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Juvenile Sockeye Salmon Population Estimates in Skilak and Kenai Lakes, Alaska, by Use of Split-beam Hydroacoustic Techniques in September 2004

by

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Alaska Department of Fish and Game

Divisions of Sport Fish and Commercial Fisheries



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Weights and measures (metric)		General		Mathematics, statistics	
centimeter	cm	Alaska Administrative Code		all standard mathematical signs, symbols and abbreviations	
deciliter	dL		AAC		
gram	g	all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.	alternate hypothesis	H _A
hectare	ha			base of natural logarithm	<i>e</i>
kilogram	kg	all commonly accepted		catch per unit effort	CPUE
kilometer	km	professional titles	e.g., Dr., Ph.D., R.N., etc.	coefficient of variation	CV
liter	L			common test statistics	(F, t, χ^2 , etc.)
meter	m	at	@	confidence interval	CI
milliliter	mL	compass directions:		correlation coefficient (multiple)	R
millimeter	mm	east	E	correlation coefficient (simple)	r
Weights and measures (English)		north	N	covariance	cov
cubic feet per second	ft ³ /s	south	S	degree (angular)	°
foot	ft	west	W	degrees of freedom	df
gallon	gal	copyright	©	expected value	<i>E</i>
inch	in	corporate suffixes:		greater than	>
mile	mi	Company	Co.	greater than or equal to	≥
nautical mile	nmi	Corporation	Corp.	harvest per unit effort	HPUE
ounce	oz	Incorporated	Inc.	less than	<
pound	lb	Limited	Ltd.	less than or equal to	≤
quart	qt	District of Columbia	D.C.	logarithm (natural)	ln
yard	yd	et alii (and others)	et al.	logarithm (base 10)	log
Time and temperature		et cetera (and so forth)	etc.	logarithm (specify base)	log ₂ , etc.
day	d	exempli gratia (for example)	e.g.	minute (angular)	'
degrees Celsius	°C	Federal Information Code	FIC	not significant	NS
degrees Fahrenheit	°F	id est (that is)	i.e.	null hypothesis	H ₀
degrees kelvin	K	latitude or longitude	lat. or long.	percent	%
hour	h	monetary symbols (U.S.)	\$, ¢	probability	P
minute	min	months (tables and figures): first three		probability of a type I error (rejection of the null hypothesis when true)	α
second	s	letters	Jan.,...,Dec	probability of a type II error (acceptance of the null hypothesis when false)	β
Physics and chemistry		registered trademark	®	second (angular)	"
all atomic symbols		trademark	™	standard deviation	SD
alternating current	AC	United States (adjective)	U.S.	standard error	SE
ampere	A	United States of America (noun)	USA	variance	
calorie	cal	U.S.C.	United States Code	population sample	Var var
direct current	DC	U.S. state	use two-letter abbreviations (e.g., AK, WA)		
hertz	Hz				
horsepower	hp				
hydrogen ion activity (negative log of)	pH				
parts per million	ppm				
parts per thousand	ppt, ‰				
volts	V				
watts	W				

FISHERY DATA SERIES NO. 11-13

**JUVENILE SOCKEYE SALMON POPULATION ESTIMATES IN SKILAK
AND KENAI LAKES, ALASKA, BY USE OF SPLIT-BEAM
HYDROACOUSTIC TECHNIQUES IN SEPTEMBER**

by

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ABSTRACT

Hydroacoustic surveys conducted from 13 to 15 September 2004 on Skilak and Kenai Lakes used split-beam sonar. A second hydroacoustic survey was conducted on Skilak Lake (5 October 2004), because the first population estimate for this lake appeared low and could have been biased. The population estimates from these two surveys of Skilak Lake were 23,089,494 and 29,036,549 fish respectively. These two population estimates were not significantly different ($F = 2.511$; $P = 0.126$) from each other so a pooled estimate was calculated. The population estimates for Skilak and Kenai Lakes were 25,684,868 and 2,634,159 fish. Annual midwater trawl surveys were conducted to estimate age composition, mean weight, and mean length of juvenile sockeye salmon. For Skilak Lake, age-0 sockeye salmon composed 97% of the total population estimate. The mean population weight and length of this cohort was 0.63 g and 40.9 mm with the weight being the smallest on record. In comparison, age-0 sockeye salmon accounted for 100% of the total fish population in Kenai Lake. The age-0 fry in Kenai Lake were approximately double the weight of fry in Skilak Lake (mean=1.27g), but they were only slightly longer at 48.5 mm when compared to Skilak Lake fry.

Key words: Alaska, Cook Inlet, Skilak Lake, Kenai River, sockeye salmon, *Oncorhynchus nerka*, split-beam, sonar, Hydroacoustics.

INTRODUCTION

In September 2004, the Alaska Department of Fish and Game (ADF&G) conducted hydroacoustic and tow-net surveys in Skilak and Kenai lakes (Kenai River drainage, Figure 1) to determine population abundance, age distribution, and size of juvenile sockeye salmon *Oncorhynchus nerka*. These surveys have been performed annually since 1986 (DeCino 2002; DeCino and Degan 2000; Tarbox and King 1988a, 1988b; Tarbox, et. al. 1993; Tarbox and Brannian 1995; Tarbox et. al. 1996). The information obtained on fall fry rearing in these major nursery lakes are used to help biologists forecast the number of sockeye salmon returning to the Kenai River (Eggers 2005). Moreover, the biological basis for the brood interaction spawner-recruit model is thought to be heavy grazing on cyclopoid copepods by large fry populations reducing survival of the subsequent year class (Carlson et al. 1999; Edmundson et al. 2003). Thus, a major goal of this project, coupled with limnological studies, is to gain a better understanding of the factors regulating the production of sockeye salmon in the Kenai River, which supports the largest runs of sockeye salmon in Upper Cook Inlet (Fox and Shields 2002).

For the 2004 fish surveys, population sizes were estimated using an echo integration procedure of data obtained from split-beam sonar (MacLennan and Simmonds 1992). The condition of the juvenile sockeye salmon was based on the size and age of fish captured in mid-water trawls. In addition, transects across each lake were geo-referenced during the hydroacoustic surveys (DeCino and Degan 2000). In this report, we describe the methods used in our lake surveys, and we provide (1) abundance estimates for juvenile sockeye salmon rearing in Skilak and Kenai lakes, (2) distributions of age, weight and length of fall fry, and (3) assessments of the pre-winter condition of fry.

METHODS

HYDROACOUSTIC SURVEYS

We used a stratified-random sampling design for the hydroacoustic surveys to distribute sampling effort in proportion to abundance and reduce the variance of the population estimate based on previous researcher's findings (Tarbox and King 1988a and b; Tarbox and Brannian 1995; Tarbox et al. 1993; Tarbox et al. 1994; Tarbox et al. 1996 and 1999). Each lake was divided into areas or subbasins and survey transects were randomly selected within each area.

The number of transects were chosen to reduce relative error to ~25% for Skilak Lake and 30% for Kenai Lake. This sample size and stratification was based on historical findings (Tarbox and Brannian 1995; Tarbox et al. 1993; Tarbox et al. 1994; Tarbox et al. 1996 and 1999). Because of the configuration of Skilak Lake, transects perpendicular to shore were surveyed within three subbasins (Figure 2), whereas in Kenai Lake, transects were surveyed within five subbasins (Figure 3). Transects were chosen based on a stratified-random design (DeCino and Degan 2000; Tarbox et al. 1996; Jolly and Hampton 1990; Figures 2 and 3). Transects were traversed at approximately 2 m/s. The acoustic vessel (7.2 m long) was powered by two 2-stroke outboard engines.

In Skilak Lake, two hydroacoustic surveys were completed. The first using a down-looking configuration only, whereas the second utilized two transducers in a multiplexing (side and down looking) configuration. We chose a side looking transducer configuration in Skilak Lake, because we wanted to test the assumption that population densities were equal in the 0–2 m and 1–5 m layers. In Kenai Lake only, a single down looking hydroacoustic survey was conducted.

For all the hydroacoustic surveys, juvenile sockeye salmon were sampled acoustically at night with a BioSonics DTx-6000¹ split beam echosounder. For specific data collection parameters on all surveys see Appendix A1. The down-looking transducer was mounted to a 1.5 m long aluminum towbody. The towbody was attached to a cable connected to a boom and towed off the boat's starboard side approximately 1 m below the water surface. The side looking transducer was mounted to a pole on the port side of the acoustic vessel at a depth of 1 m. The transducers transmitted digital data via a direct connection data cable to the echosounder. The echosounder was connected to a laptop computer via ethernet data connection. For geo-referenced transect routes, we used a Garmin GMAP model 175 global positioning system (GPS). Acoustic digital data were collected and stored on a laptop computer hard drive. Configuration parameters (Appendix A1) were input into BioSonics Visual Acquisition data collection software. Water temperature was measured with a YSI model 58 digital thermistor and input to the environmental variables of the program. Twelve-volt batteries powered the acoustic system and the laptop computer.

Acoustic data were stored (hard drive) and transported to the area office where they were uploaded into the area office network for access by analysis programs. The acoustic data were edited by use of SonarData Echoview analysis software. Acoustic data were first bottom edited to remove bottom echoes. After bottom editing was complete, individual target information was processed and saved for estimation of in-situ target strength and sigma (σ) the absolute backscattering coefficient.

Target strength and σ computations were performed using a macro built by Aquacoustics Inc. For each lake, this macro appended all transects and calculated in-situ target strengths and σ 's from each detected target. Targets were filtered to include only those echoes near the beam center (0 to –3dB off axis). Target number and average σ were derived and put into 5 m strata. Generally, the entire lake average σ was input to a spreadsheet to compute densities for each transect using echo-integration. However, if the stratum differed by more than 20% of the mean σ computed for the entire lake and target density was greater than 5% of total targets used to

¹ Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

compute average σ then a different σ would be used to compute densities of other fish targets (Appendix A2–A4).

A fish density estimate was computed for each transect and expanded for each area from which they were collected. The echo integrator compiled data in one report along each transect and sent outputs to computer files for further reduction and analysis. The total number of fish (\hat{N}_{ij}) for area stratum (i) based on transects (j) was estimated across depth stratum (k). \hat{N}_{ij} consisted of an estimate of the number of fish detected by hydroacoustic gear in the mid-water layer (1–51 m from transducer face) layer (\hat{M}_{ij}) and an estimate of the number of fish in the surface layer \hat{S}_{ij} (0–2 m), i.e.

$$\hat{N}_{ij} = \hat{S}_{ij} + \hat{M}_{ij} . \quad (1)$$

The mid-water component was estimated as:

$$\hat{M}_{ij} = a_i \sum_{k=1}^K M_{ijk} , \quad (2)$$

where a_i represented the surface area (m^2) of area stratum i which was estimated using a planimeter and USGS maps of Skilak and Kenai Lakes, and \hat{M}_{ijk} (number/ m^2) was the estimated mean fish density in area i depth k across transect j . The depth would be less than the maximum 50 m if the bottom was detected within depth stratum k anytime along the transect.

In order to estimate the number of fish unavailable to the hydroacoustic gear in a down looking configuration because of their location near the surface, the fish density in the upper stratum (\hat{S}_{ij}) was assumed equal to the density in the first stratum echo integrated in the lake (DeCino and Degan 2000). That assumption is based on lake morphometry and percent volume sampled in post-processing analysis. The estimated numbers of fish near the surface (0–2 m) in area i was

$$\hat{S}_{ij} = a_{is} m_{ijk} , \quad (3)$$

where a_{is} was the estimated area (m^2) of the surface stratum (0–2 m), and m_{ijk} is 2/5 of the mean fish density (DeCino and Degan 2000) in the first ensonified depth stratum (1–5 m below transducer face) of transect j .

Using transects as the sampling unit (Burczynski and Johnson 1986), fish abundance in area i (\hat{N}_i) was estimated from the mean abundance for all transects j in the area, or

$$\hat{N}_i = J^{-1} \sum_{j=1}^J \hat{N}_{ij} , \quad (4)$$

and its variance was estimated as

$$v(\hat{N}) = \sum (\hat{N}_{ij} - \hat{N}_i)^2 (J - 1)^{-1} J^{-1} . \quad (5)$$

Total fish abundance (\hat{N}) for each lake was estimated as the sum of the area estimates and the variance of \hat{N} was estimated as the sum of the area variance estimates.

The abundance of juvenile sockeye salmon in each lake (\hat{N}_s) was estimated as:

$$\hat{N}_s = \hat{N}\hat{P}_s \quad (6)$$

where \hat{P}_s was the estimated proportion of total fish targets that were juvenile sockeye salmon in the lake. Age-specific numbers of juvenile sockeye salmon (\hat{N}_{sa}) were estimated as

$$\hat{N}_{sa} = \hat{N}_s\hat{P}_a \quad (7)$$

where \hat{P}_a was the estimated proportion of age-a sockeye salmon in the fish population.

Variance estimates were calculated as

$$v(\hat{N}_s) = \hat{N}^2 v(\hat{P}_s) + P_s^2 v(\hat{N}) - v(\hat{P})v(\hat{N}) \quad (8)$$

$$v(\hat{N}_{sa}) = \hat{N}^2 v(\hat{P}_a) + P_a^2 v(\hat{N}) - v(\hat{P}_a)v(\hat{N}) \quad (9)$$

The covariance between proportions and abundance is unlikely because P_s and P_a are always close to 1.0.

Two surveys were completed in Skilak Lake on 13 September and 5 October 2004. These two surveys were done at night, in dark moonless conditions, to assess the potential of “missing” fish detected by the hydroacoustic sonar gear (DeCino et al. 2004). A randomized block ANOVA with survey as the treatment and the three areas as the blocks was utilized to test whether the two population estimates differed. In addition, Barlett’s test for homogeneity of variance (Zar 1984) was used to test whether the variance of the surveyed populations was the same for each independent acoustic survey. If the population estimates were not significantly different from each other, transects from each survey’s respective areas were added to each other and population estimates and variances were calculated as above.

AGE, WEIGHT, AND LENGTH (AWL) SURVEYS

Mid-water trawl (tow netting) surveys were conducted in both lakes to estimate the species composition of acoustic targets and the age composition, mean wet weight (g), and mean fork length (mm) of juvenile sockeye. In both lakes, scales from juvenile sockeye salmon 55 mm and greater were used to determine the fishes age, because juvenile sockeye salmon <55 mm were found to be nearly all age 0 (David Westerman, Commercial Fisheries Biologist, ADF&G Soldotna, personal communication). Sampling in Skilak Lake utilized a stratified cluster and stratified two-stage sampling technique (Scheaffer et al. 1986; Cochran 1977; see Carlson memorandum Appendix A5). Areas were the same as those used in the hydroacoustic sampling. Depth strata were developed to account for potential vertical variation in species and age composition. Three depth strata were defined: surface (0–10 m), mid-depth (15–25 m) and deep (30–40 m). Each tow was defined as a primary sampling unit and a minimum of three tows were conducted in each stratum. All fish captured in each tow were identified to species. For AWL

information a minimum sample size of 1000 and 500 sockeye salmon fry were collected from Skilak and Kenai Lakes, respectively..

We used the same stratified random sampling technique in Kenai Lake; however, three areas and two depth strata were defined. The three sampling areas consisted of area one (identical to the hydroacoustic area one), area two (combining hydroacoustic areas two and three) and area three (combining hydroacoustic areas four and five). Two depth strata were sampled in Kenai Lake, i.e. surface (0–10 m) and mid-depth (15–25 m). The 30–40 m stratum was not sampled, because historically very few fish were captured in this stratum (Tarbox et al. 1999).

Fish captured in Skilak Lake were measured to the nearest 1 mm in the field. Scales were removed from sockeye salmon juveniles greater than 55 mm and all fry placed into individual pre-weighed scintillation vials. Vials were returned to the laboratory in Soldotna where they were weighed and frozen for subsequent lipid and bomb calorimetry analysis. Fresh wet weights were converted to formalin-fixed weight based on Shields and Carlson (1996) conversion data. All fish collected from Kenai Lake were enumerated, identified, and preserved in 10% formalin. In the laboratory juvenile sockeye salmon were measured to the nearest millimeter (fork length), weighed (wet) to the nearest 0.1 g, and the age determined from scale samples using criteria outlined by Mosher (1969).

RESULTS

SKILAK LAKE

Two hydroacoustic surveys were conducted on Skilak Lake. One on 13 September and the other 5 October 2004. For target strength estimation, a total of 21,510 and 25,540 echoes were used to calculate a mean target strength of -56.7 and -56.4 dB with a standard deviation's (SD) of 3.04 and 3.10 dB for surveys 1 and 2, respectively. The mean and standard deviations for the backscattering coefficient (σ) used for echo integration were $2.83 \times 10^{-6} \pm 3.42 \times 10^{-5}$ and $2.99 \times 10^{-6} \pm 3.33 \times 10^{-6}$ (Table 1). The population estimates obtained from the two surveys were 23,089,494 and 29,036,549 fish, but the two estimates were not significantly different from each other ($F=2.511$; $P=0.126$). Therefore, data from the two surveys were combined, providing a pooled estimate of approximately 25,685,000 fish with a standard error (SE) of 2,894,633 fish. Of the estimated total population of juvenile sockeye salmon, approximately 53% were detected in Area 1 (Table 2, Figure 2). In addition, the largest proportion of total fish targets in the 0–5 m depth strata was detected in Area 1 (Table 2), causing our estimate of the fish population in the surface layer (0–2 m) to also be greatest in this area. We estimated the total fish population in the upper 2 m of the water column in Skilak Lake was approximately 1,233,505 fish.

During our tow-net surveys, 10,432 fish were captured of which 10,421 or 99.9 % were juvenile sockeye salmon. Of these, 1,000 were subsampled to estimate mean wet weight and fork length (AWL). From these 1,000 fish, scales were collected from only 47 individuals (>55 mm length) to estimate their age. Age-0 juvenile sockeye salmon accounted for 97.1 % (SE=0.009%) of the total fish population estimate. The remaining 2.8 % (SE=0.009%) were age-1 sockeye salmon. Therefore, approximately 24,940,135 (SE=2,820,352) and 711,475 (SE=244,487) sockeye salmon were aged 0 and 1+ fish, respectively (Table 3). The mean population weight (converted to a formalin-preserved weight) and length of age-0 sockeye salmon was 0.63 g (SE=0.009 g) and 40.9 mm (SE=0.17 mm). In comparison, age-1 juvenile sockeye averaged 2.12 g (SE=0.14 g) and 62.4 mm (SE=0.95 mm; Table 4, Figure 4).

KENAI LAKE

A total of 7,103 echoes were used to estimate target strengths in Kenai Lake. The mean target strength was -55.26 dB with a SD of 3.79 dB. The mean σ was 4.14×10^{-6} with a SD of 3.32×10^{-6} . This σ produced a population estimate of 2,634,200 (SE=235,835) fish. Of these 2,634,200 fish, 165,122 fish were estimated to occur in the surface layer (upper 0–2 m) (Table 2). The greatest density and proportion of the total juvenile sockeye salmon population was located in Area 2 (Table 2).

Based on our mid-water trawls conducted in Kenai Lake, sockeye salmon accounted for 100% (SE=0%) of the population. A total of 561 fish were captured of which 27 were >55 mm which were sampled for age. All subsampled sockeye fry were age-0 fish (Table 3). The mean population weight and length of the age-0 cohort was 1.27 g (SE=0.02 g) and 48.5 mm (SE=0.27 mm), respectively (Table 4, Figure 4). Juvenile sockeye salmon in Kenai Lake were both significantly longer ($F=966.1$, $p=0.00$) and heavier ($F=1812.6$, $p=0.00$) than the Skilak Lake fish in 2004 (Figure 4).

DISCUSSION

The 2004 population estimates of juvenile sockeye salmon in both Skilak and Kenai lakes ranked the third largest since surveys were initiated in 1986 (Figure 5). These juvenile sockeye salmon abundance estimates exhibit considerable year-to-year variation and there appears to be little overall trend in the time series (Figure 5). However, the combined lake 2004 population estimate is about 7.0 million more than the 18.9 million 18-year mean abundance.

Skilak Lake consistently supports more sockeye salmon fry than Kenai Lake. The Skilak Lake population estimate is approximately 5.2 million fish more than its historical mean. The highest population estimate (1993) was approximately 33 million fry (Tarbox et al. 1996), and the lowest population estimate (1996) was 5.2 million fish. The average population size since 1986 is 16.2 million fish with a SD of 8.79 million fish.

The 2004 Kenai Lake population estimate of 2.4 million fish is the eighth highest since inception of acoustic estimates in 1986 (Figure 5). Juvenile sockeye salmon estimates have ranged from 768,000 in 1996 to 6.2 million in 1988 (Tarbox et al. 1996). The average population since 1986 is 2.67 million fish with a SD of 1.55 million. The 2004 sockeye salmon population estimate for Kenai Lake is about 33,755 fish below the historical mean population size.

The target strengths of the juvenile sockeye salmon measured with the split-beam transducer in 2004 were within reported ranges of target strengths measured using a dual-beam hydroacoustic system (see Tarbox et al. 1996). In addition, juvenile sockeye salmon lengths and weights followed historical trends. Kenai Lake, on average, has produced larger fish in both length and weight compared with Skilak Lake. This is most likely a result of density-dependent effects that occur in Skilak Lake.

Similar to the historical population estimates, historical length and weight measurements show considerable year to year variation in Skilak Lake (Figure 6). For age-0 sockeye salmon in Skilak Lake, the 2004 mean length and weight were 16 and 49% less, respectively, than the historical means. A regression equation relating fall fry weight to their abundance (Edmundson et al. 2003) predicted a 1.03 g mean weight for sockeye salmon fry in Skilak Lake, whereas actual mean weight was 0.63 g. The small size of the sockeye salmon fry in Skilak Lake this year

was likely due in part to the low total copepod biomass in the lake (mean=282 mg/m², 2nd lowest biomass observed since 1986). We are concerned that these small fry may suffer elevated overwinter mortality, if they lack sufficient energy reserves to survive the winter fast. We are developing an overwinter mortality model employing measurements of whole body energy content of juvenile sockeye salmon sampled in the fall. In 2005, we will initiate a project to estimate the population size of smolts emigrating from the Kenai River watershed as a means to validate model estimates of overwinter mortality.

We conducted two acoustic surveys on Skilak Lake in 2004. In the first survey we employed only a down-looking transducer. In the second hydroacoustic survey on Skilak Lake, we used both down-looking and side-looking transducers in a multiplexing configuration. We used the down-looking transducer to estimate the fish population in Skilak Lake as in the first survey. We used the data from the side-looking transducer to estimate fish density in the upper 2 m of the water column for comparison to surface-layer density estimates derived from the 0 to 5 m layer (below the downlooking transducer).

Our effort to estimate fish density in the upper 2 m of the water column in 2004 had mixed results. The transducer was attached to a rigid mount on the gunwale and any slight disturbance (movement) in the vessel would result in noise/reverberation registered in the digital data stream. In addition to the movement, a slight breeze would produce noise on the surface which if strong enough would rock the boat and cause the echogram to be completely saturated in reverberation. Transducer aiming was also difficult. For instance, if the transducer attitude was oblique to the horizontal/perpendicular axis of the boat and looking upward, noise could be produced in the entire ensonified range. Therefore transducer aiming by this method was accomplished by lowering the transducer to a depth of 1 m and then rotating the transducer up to detect surface noise at 20-25 m range. After surface noise was detected then one would have to not “rock” the boat to get a noise free range. This however turned out to be difficult for several reasons. First at the end of each transect, the pole-mounted transducer was brought to the surface in order to travel to the next transect. On the subsequent transect, the pole and transducer were lowered and re-aimed. This was very time consuming and the transducer attitude would change as noted before. Second, if surface water conditions were very calm (approaching mirror like), the surface could not be detected, because sound waves were not reflected back to the transducer. Third, if the wind speed increased too much, the entire ensonified range was too noisy to estimate fish density.

We feel that it may be important to ensonify the 0 to 2 m layer of the water column, because of behavior often exhibited by juvenile sockeye salmon. For instance, fry could be feeding in the surface layer under full moon conditions, so we could underestimate fish density in that portion of the water column using our standard method. Even though our data do not indicate high numbers in the upper layer of the water column in either survey (1% and 2% of total targets in Skilak Lake surveys one and two, respectively, Appendices A2 and A3), other researchers have noted that juvenile sockeye salmon can occur in high concentrations near the surface in glacially turbid lakes. For example, it has been demonstrated, at certain times of the year, a high proportion of total copepod biomass is located near the surface in Tustumena Lake likely causing juvenile sockeye salmon to aggregate in a shallow surface layer. This is most likely due to the high glacial silt load in the water column (Patrick Shields, Commercial Fisheries Biologist, ADF&G, personal communication, Soldotna).

In 2003, DeCino et al. (2004) observed more fish targets in the upper three depth strata during the first survey compared to the second survey, possibly due to greater light penetration and possible foraging behavior in full moonlight conditions (Gliwicz 1986) during the first survey. During their second survey, no moonlight conditions existed and greater numbers of targets were observed toward the middle of the water column compared to the first survey. This change in vertical distribution may have been due to differences in fish behavior or perhaps sampling error.

In 2004, 97% and 99% of all fish targets in Skilak Lake occurred in the upper 45 m of the water column during surveys 1 and 2, respectively (Appendix A2 and A3). In the first survey, there were larger targets at depth (45 m and deeper), but the same sigma was used to integrate those “other” fish (Figure 7), because those targets were not determined to be in great numbers from examination of the echogram. These “other” deep targets are most likely other adult salmonids such as: rainbow trout (*O. mykiss*), Dolly Varden (*Salvelinus malma*), lake trout (*S. namaycush*), and adult salmon.

Even though our two population estimates of juvenile sockeye salmon in Skilak Lake differed by approximately 6 million fish, they were not significantly different from each other, so the data were pooled. MacLennon and Simmonds (1992) suggested that data from replicate surveys can be pooled. Although, conducting multiple acoustic surveys is more costly, this approach allows us to better understand effects of survey conditions on the estimate and increase the precision of the estimate.

However the question remains why relatively large, non-significant, differences in population estimates existed in 2004. Historically, until the last two years, one hydroacoustic survey in the fall was used to estimate juvenile sockeye salmon populations in Kenai and Skilak Lake. In 2004 the mean fish weight was the smallest since 1986. Fish targets appear to aggregate in certain areas of the lake, particularly near shore, and these smaller fish could recruit to the pelagic population later in the fall. Additionally, larger resident populations, such as rainbow trout, could migrate into the lake to overwinter. In addition to behavioral movements of fish, sampling error could potentially cause significant differences between population estimates. During the second survey in October we were not able to complete the last transect in area 1 because of the difficulty using the side looking transducer mount. We therefore lost one transect which could have reduced the average population for that area and hence a less total population estimate. If more transects per area were surveyed then whole lake surveys would take greater than one night to complete, potentially biasing the results due to fish movement between surveys. This potential bias could be reduced by conducting the second survey as soon as possible after the first. We believe that at a minimum we should conduct two hydroacoustic surveys on Skilak Lake as a standard procedure to examine the temporal variability of the population estimates. However, the use of a more intensive adaptive sampling protocol in detected areas of greater juvenile sockeye salmon abundance (i.e. near shore environments) may allow us to further reduce the variance of population estimates. Using an adaptive sampling strategy to sample fish concomitant with limnological studies would also provide robust data sets to help us better understand abiotic and biotic factors influencing the distribution, behavior and ecology of juvenile sockeye salmon.

ACKNOWLEDGEMENTS

The authors would like to thank Dave Westerman, Bill Glick, and Jim Lazar of ADF&G for assisting during field operations. Thanks to Don Degan for acoustic support and finally thanks go to Sandi Seagren for help in report preparation.

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TABLES AND FIGURES

Table 1.—Average target strength (dB) and backscattering coefficient (σ) for echo integration used to estimate the population size of juvenile sockeye salmon in Skilak and Kenai lakes.

Lake	Number Targets	Average Target Strength (dB)	Average Backscattering Coefficient Sigma (σ)
Skilak 1 ^a	21,510	-56.67(3.04)	2.83×10^{-6} (3.42×10^{-6})
Skilak 2 ^a	25,540	-56.38(3.10)	2.99×10^{-6} (3.33×10^{-6})
Kenai	7,103	-55.26(3.79)	4.14×10^{-6} (3.32×10^{-6})

^a September 13, 2004.

^b October 5, 2004.

Table 2.—Estimated number of total fish in Skilak and Kenai Lakes, Alaska in September 2004.

Lake	Area-Survey	Transect	Estimated Number of Fish			Mean	Area Variance
			Surface	Midwater	Total		
Skilak	1-1	1	1,554,165	16,071,580	17,625,745	13,533,550	6,742,745,525,859
	1-1	2	44,125	9,811,644	9,855,768		
	1-1	3	73,417	5,689,803	5,763,219		
	1-1	4	226,782	6,956,637	7,183,419		
	1-1	5	545,252	8,790,001	9,335,252		
	1-1	6	153,003	8,595,639	8,748,642		
	1-2	1	617,147	10,680,269	11,297,416		
	1-2	2	490,912	22,443,208	22,934,121		
	1-2	3	378,238	10,501,304	10,879,542		
	1-2	4	415,051	9,867,790	10,282,841		
	1-2	5	2,383,267	32,579,813	34,963,079		
	2-1	1	90,160	4,939,559	5,029,719	7,122,547	1,195,373,908,309
	2-1	2	85,578	4,663,759	4,749,336		
	2-1	3	121,111	10,382,301	10,503,413		
	2-1	4	1,004,872	6,757,897	7,762,769		
	2-2	1	108,279	5,091,999	5,200,278		
	2-2	2	75,558	2,795,169	2,870,726		
	2-2	3	147,340	11,124,312	11,271,652		
	2-2	4	204,814	9,387,666	9,592,480		
	3-1	1	499,161	4,779,103	5,278,264	5,028,771	440,797,652,627
	3-1	2	843,286	3,877,354	4,720,640		
	3-1	3	313,029	8,055,415	8,368,444		
	3-1	4	633,945	6,303,417	6,937,362		
	3-2	1	57,360	3,018,634	3,075,994		
	3-2	2	159,668	3,533,329	3,692,996		
	3-2	3	256,092	4,900,725	5,156,817		
	3-2	4	263,164	2,736,491	2,999,654		
TOTAL						25,684,868	8,378,917,086,794

-continued-

Table 2.–Page 2 of 2.

			Estimated Number of Fish			Area	
Lake	Area	Transect	Surface	Midwater	Total	Mean	Variance
Kenai	1	1	0	141,278	141,278	156,430	1,084,151,657
		2	2,440	91,835	94,276		
		3	0	249,530	249,530		
		4	0	140,637	140,637		
	2	1	0	846,725	846,725	723,603	21,414,585,446
		2	149,100	976,725	1,125,825		
		3	66,521	515,100	581,621		
		4	18,981	232,132	251,113		
		5	80,037	732,697	812,734		
	3	1	74,876	748,857	823,734	737,648	10,211,908,919
		2	50,985	971,099	1,022,084		
		3	0	586,818	586,818		
		4	2,426	439,578	442,004		
		5	53,045	760,555	813,600		
	4	1	6,334	301,694	308,028	725,663	18,794,837,394
		2	41,283	1,064,114	1,105,397		
		3	67,534	477,429	544,963		
		4	33,101	782,702	815,803		
		5	116,895	737,228	854,123		
	5	1	2,983	143,907	146,890	290,814	4,112,478,265
		2	0	176,066	176,066		
		3	1,554	212,835	214,390		
		4	69,190	397,952	467,142		
		5	0	511,544	511,544		
		6	0	228,855	228,855		
TOTAL						2,634,159	55,617,961,682
TOTAL FOR BOTH LAKES						28,319,026	8,434,535,048,476

Table 3.—Estimated fish population sizes and contributions of age-0 and age-1 sockeye salmon to the total fish population in Kenai and Skilak lakes, night surveys. September and October 2004.

Lake	Estimated Total Fish	Standard Error (SE)	Estimated Juvenile Sockeye	Standard Error (SE)	% Age-0	Total Age-0	Standard Error (SE)	% Age-1	Total Age-1	Standard Error (SE)
Skilak	25,685,000	2,894,633	25,657,917	2,891,715	97.5	24,940,135	2,820,352	2.5	711,475	244,487
Kenai	2,634,200	235,835	2,634,200	235,835	100	2,634,200	235,835	0	0	0
Total	28,319,200	2,904,224	28,292,117	2,901,316		27,583,335	2,830,195		711,475	244,487
Variance	8.4 x 10 ¹²		8.4 x 10 ¹²			8.1 x 10 ¹²			6.0 x 10 ¹⁰	

Table 4.—Average age, weight and length of juvenile sockeye salmon captured in midwater trawl surveys, September 2004.

Lake	n	Age-0		n	Age-1	
		Average Length (mm)	Average Weight (g)		Average Length (mm)	Average Weight (g)
Skilak ^a	975	40.9 (0.17)	0.53 (0.009)	25	62.4 (0.95)	1.95 (0.14)
Skilak ^b	975	40.9 (0.17)	0.63 (0.009)	25	62.4 (0.95)	2.12 (0.14)
Kenai ^b	561	48.5 (0.27)	1.27 (0.02)	0	0	0

Note: Standard Errors (SE) are in parenthesis.

^a Fresh weight.

^b Formalin preserved weight.

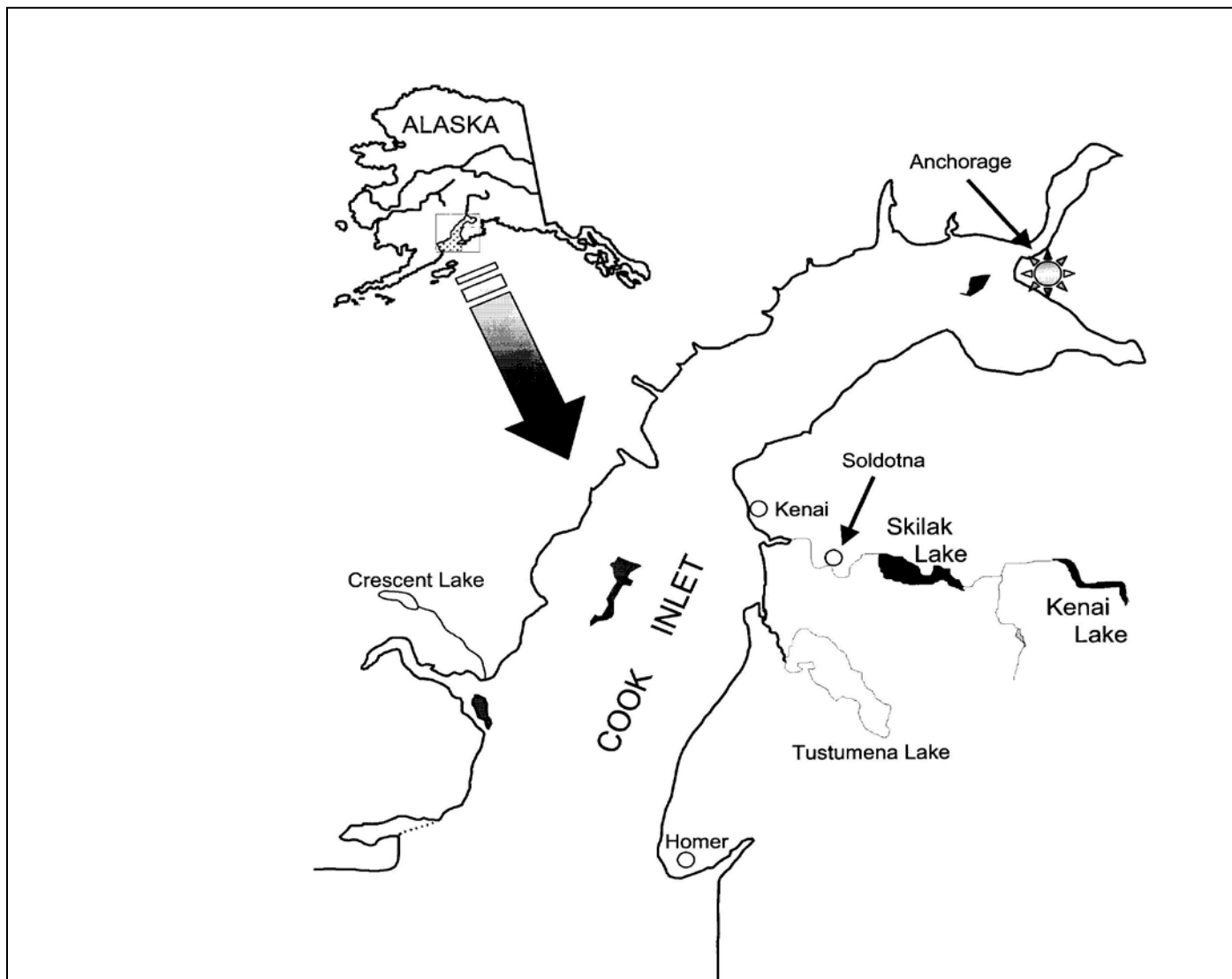
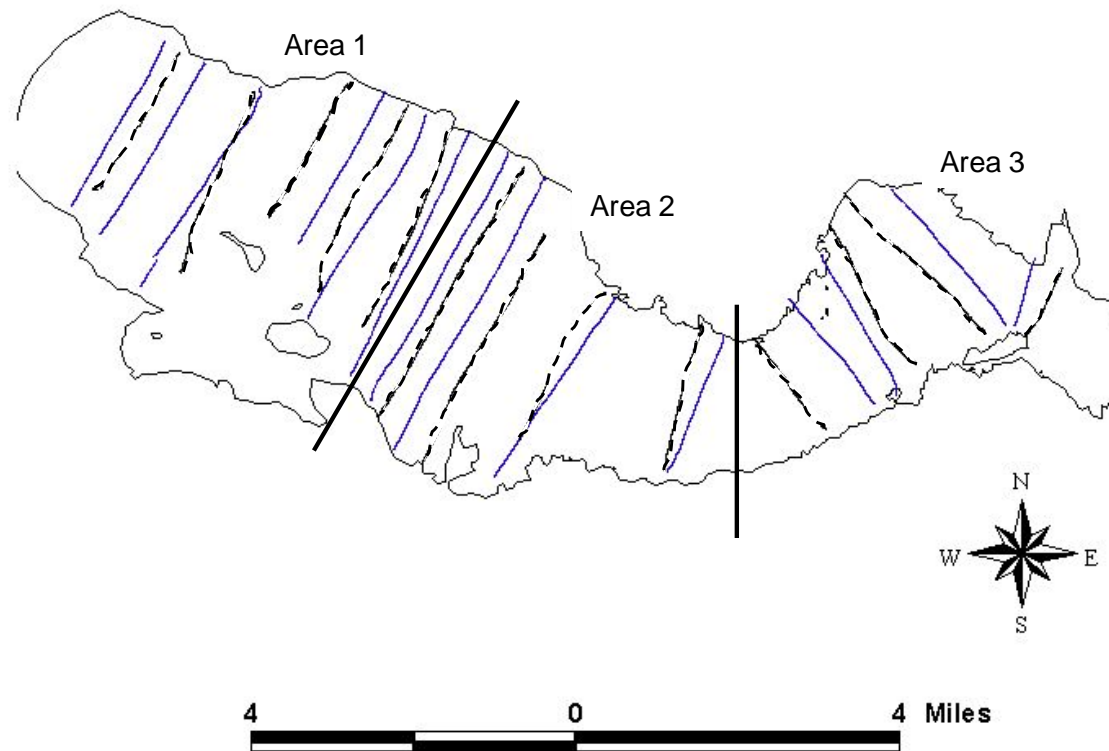


Figure 1.-Location of Skilak and Kenai Lakes.

Skilak Lake Transects September 13 and October 5, 2004



Note: Dashed line is survey 1 and solid line is survey 2.

Figure 2.—Transects for Skilak Lake hydroacoustic survey on September 13 and October 5, 2004.

Kenai Lake Transects September 14, 2004

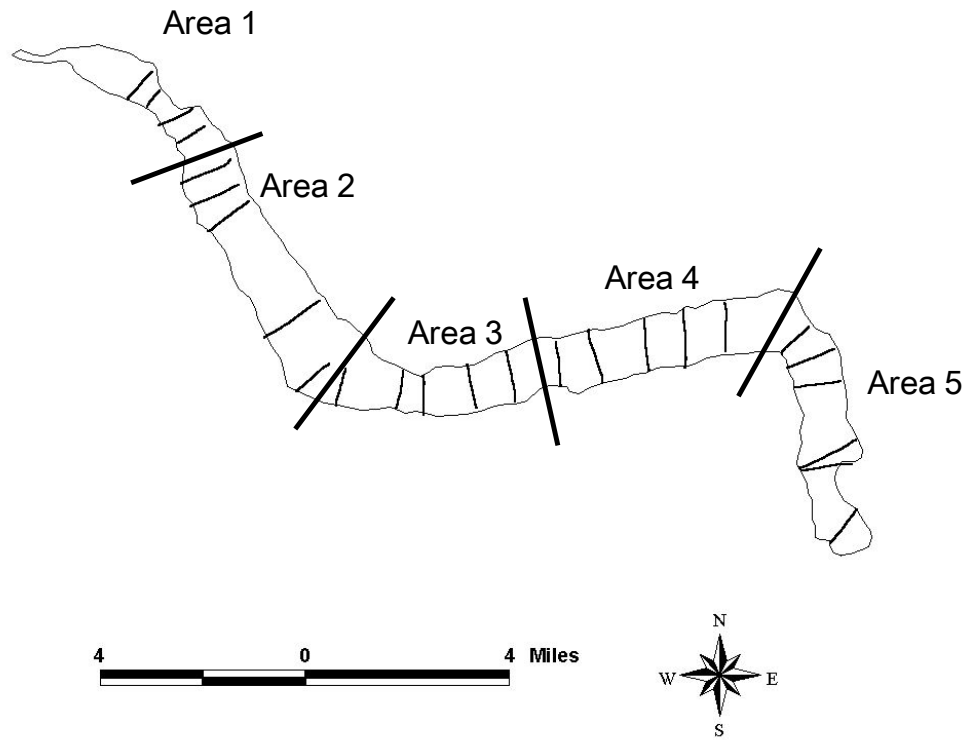
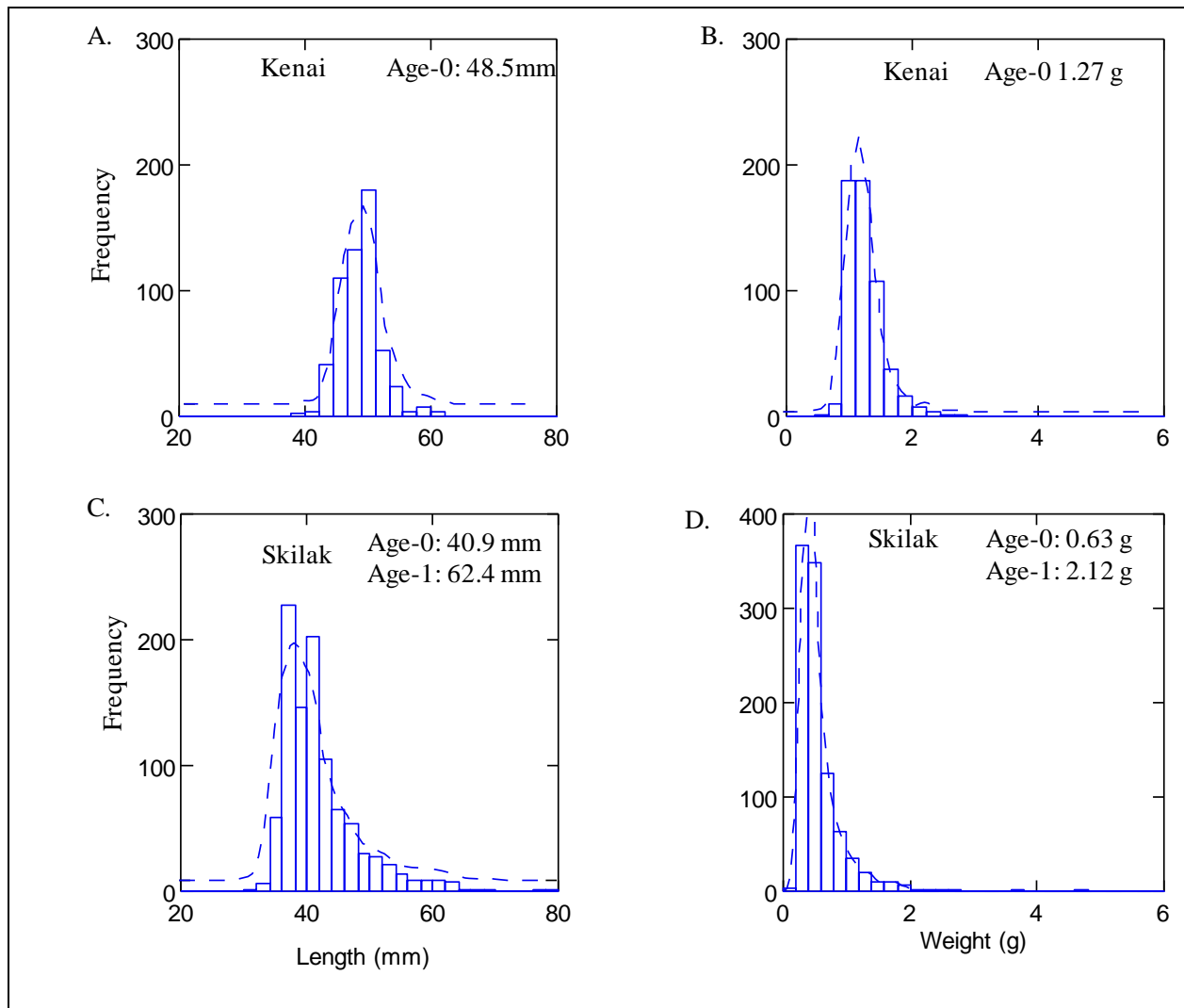


Figure 3.—Transects run in Kenai Lake September 14, 2004.



Note: Also shown are the mean sizes for the age-0 and age-1 cohorts. Dashed line is the non-parametric (kernel) density function.

Figure 4.—Size distribution of sockeye fry collected from (A–B) Kenai and (C–D) Skilak lakes in September 2004.

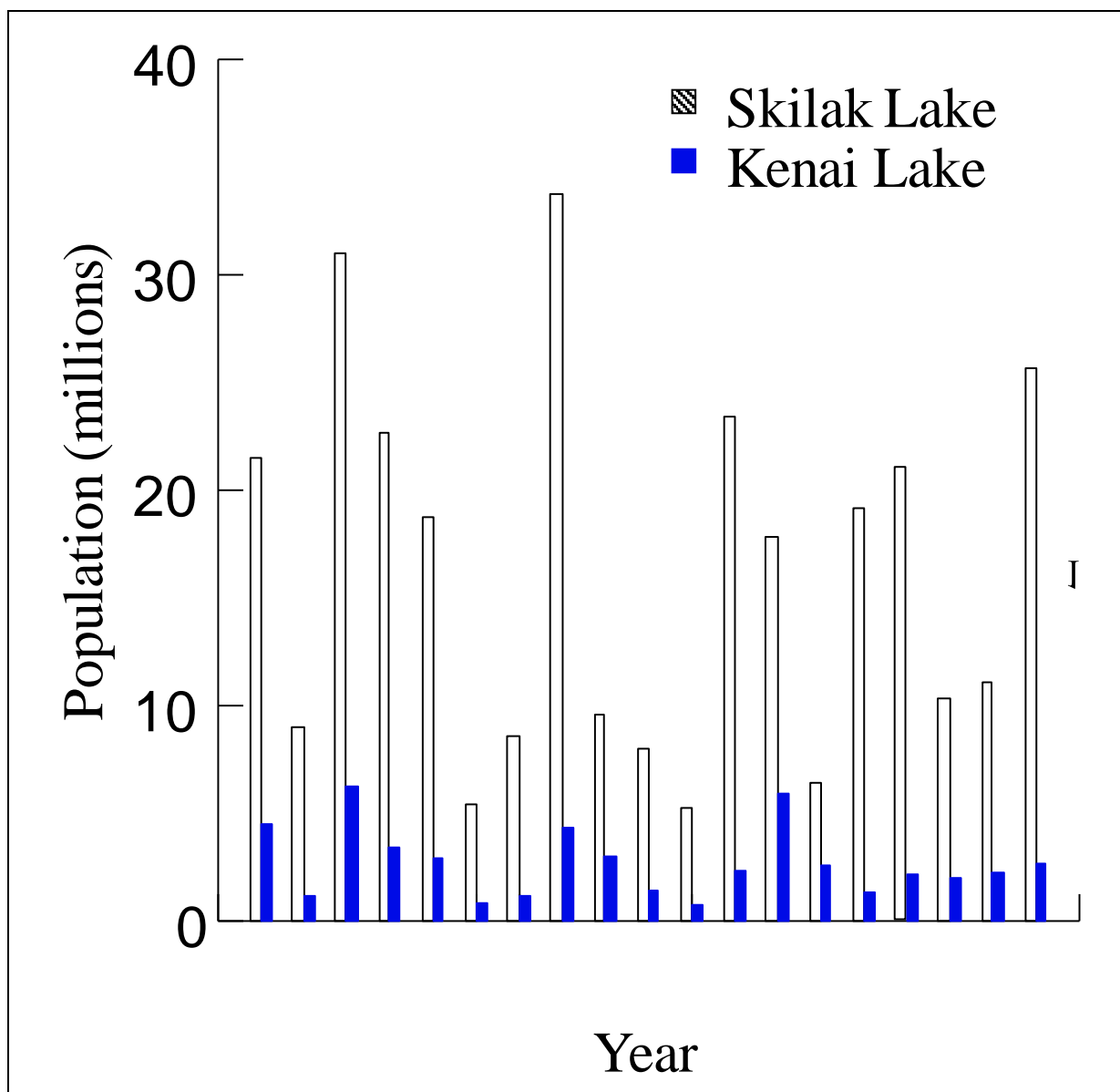


Figure 5.—Historic population estimates for Kenai and Skilak Lakes.

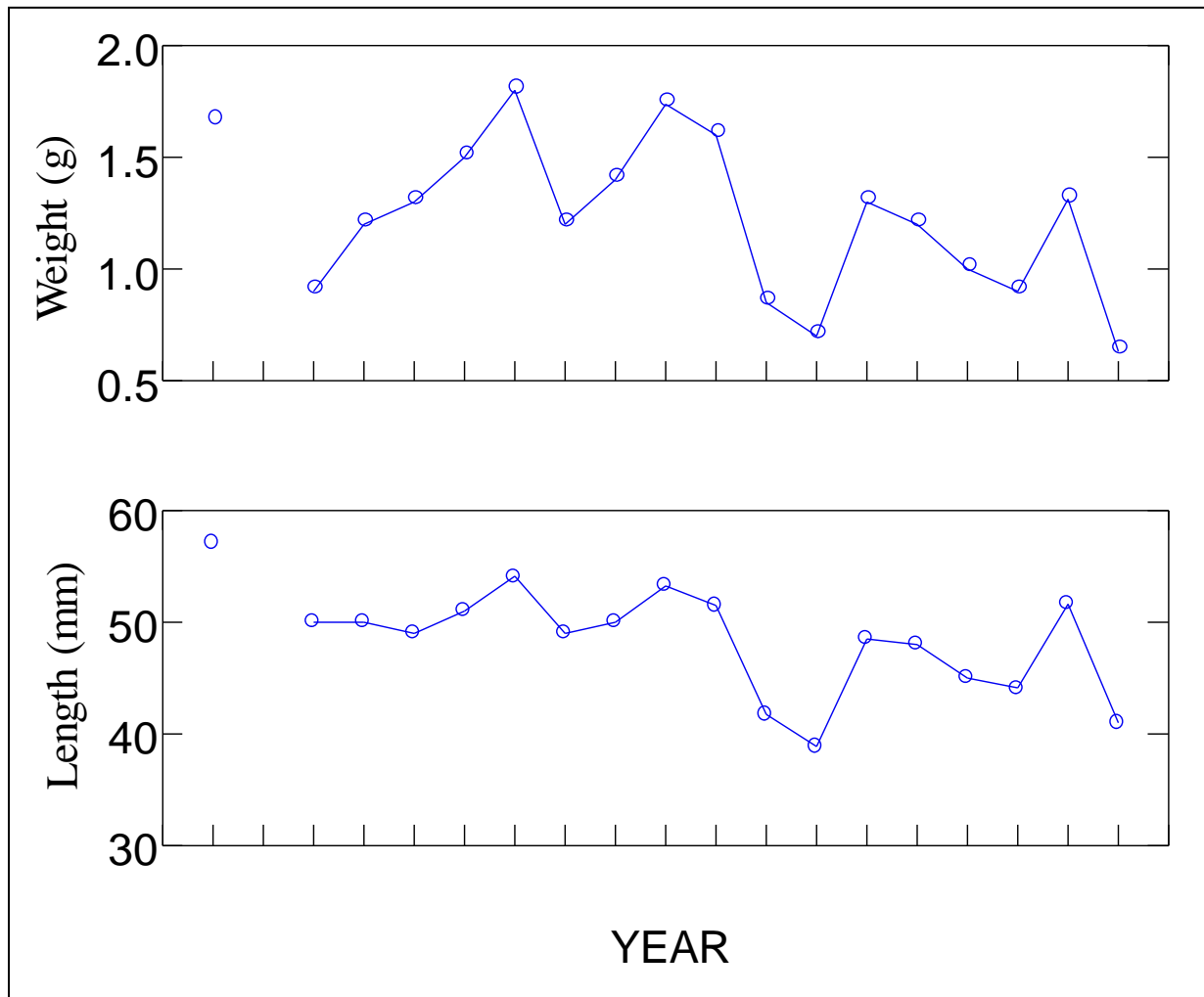
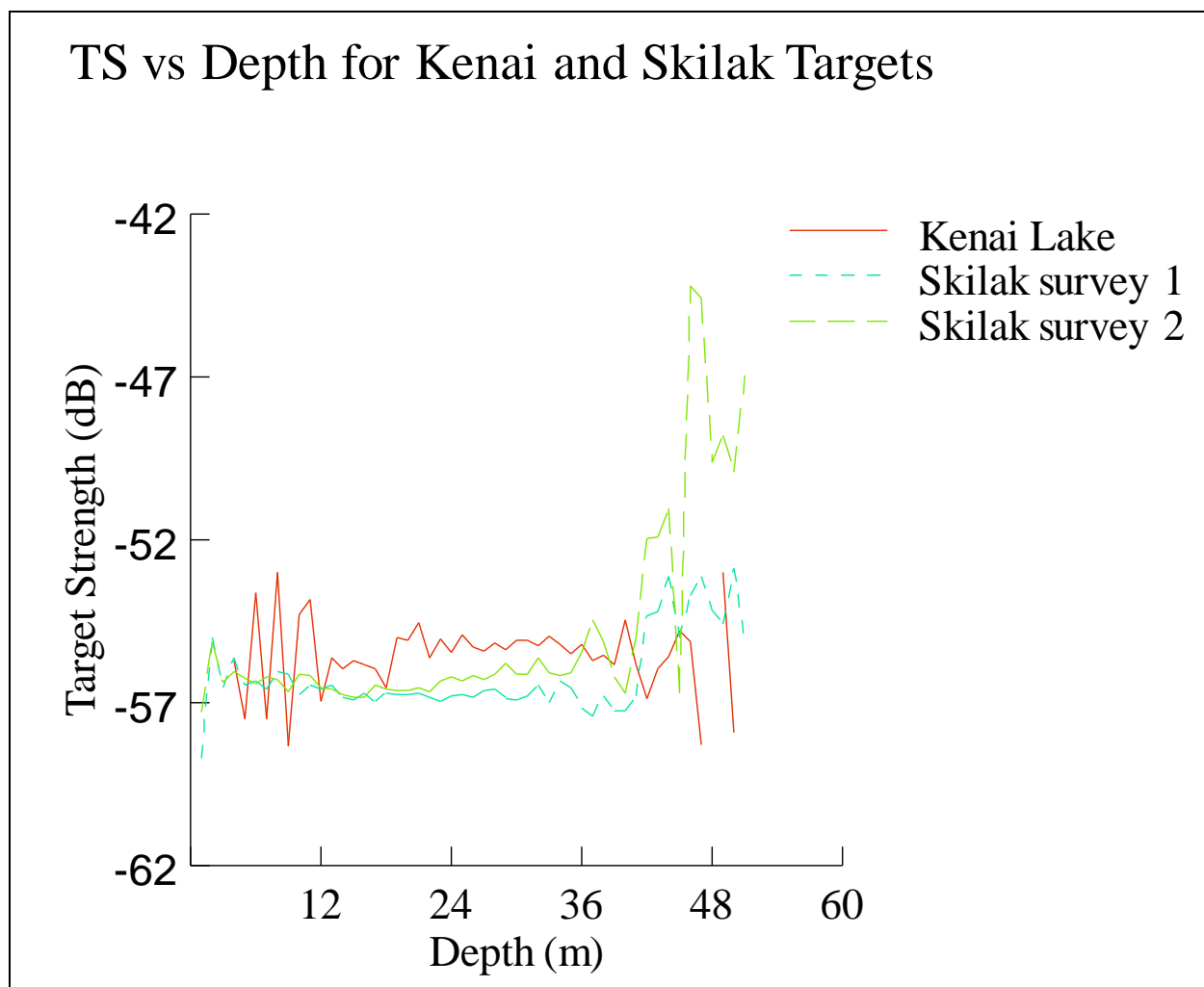


Figure 6.—Historical mean lengths and weights for Age-0 Skilak Lake juvenile sockeye salmon.



Note: Skilak Lake had two surveys, September 13 and October 5, 2004.

Figure 7.—Target Strength vs Depth for Kenai and Skilak Lake hydroacoustic surveys in September 2004.

APPENDIX A

Appendix A1.–Acoustic data collection parameters for lake surveys in 2004.

Lake	Skilak		Skilak	Kenai
Date	September-04		October-04	September-04
Configuration	Down	Down	Side	Down
Frequency (kHz)	208	201	201	208
Beam size (degree)	6.6 Circular	8.4 X 3.8 Elliptical	6.4 Circular	6.6 Circular
Mode	Split	Split	Split	Split
Pulse duration (ms)	0.4	0.2	0.2	0.4
Sample range (m)	1-65m	1-75m	1-35m	1-65m
Water temperature (C)	10	7	7	9
Transducer depth (m)	1	1	1	1
Threshold (dB)	-65	-65	-65	-65
Ping rate (pps)	2	4	4	2

Appendix A2.–Mean backscattering coefficient (s) for the September 13, 2004 hydroacoustic survey in Skilak Lake.

Skilak Strata	Number Targets	Sigma (σ)	Mean σ
			Depth σ
0–5 m	13	3.40E-06	107.36
5–10 m	383	3.19E-06	115.00
10–15 m	1,465	2.92E-06	104.91
15–20 m	3,887	2.65E-06	99.22
20–25 m	6,547	2.61E-06	93.62
25–30 m	5,104	2.57E-06	92.49
30–35 m	2,386	2.68E-06	91.42
35–40 m	852	2.72E-06	95.87
40–45 m	342	3.62E-06	120.81
45–50 m	299	1.07E-05	191.66
50–55 m	232	7.59E-06	158.96
Total	21,510	2.83E-06	100.00

Appendix A3.—Mean backscattering coefficient (s) for the October 5, 2004 hydroacoustic survey in Skilak Lake.

Skilak Strata	Number Targets	Sigma (σ)	Mean σ
			Depth σ
0–5 m	13	4.95E-06	144.41
5–10 m	554	2.96E-06	98.26
10–15 m	2,383	2.99E-06	102.65
15–20 m	4,647	2.74E-06	99.14
20–25 m	7,577	2.75E-06	97.16
25–30 m	6,428	2.96E-06	95.43
30–35 m	2,962	3.39E-06	100.59
35–40 m	782	4.02E-06	114.20
40–45 m	137	4.70E-06	122.51
45–50 m	40	2.08E-05	199.60
50–55 m	17	2.22E-05	176.99
Total	25,540	2.99E-06	100.00

Appendix A4.—Mean backscattering coefficient (s) for the September 14, 2004 hydroacoustic survey in Kenai Lake.

Kenai Strata	Number Targets	Sigma (σ)	Mean σ
			Depth σ
0–5 m	4	2.20E-06	53.12
5–10 m	15	4.07E-06	98.20
10–15 m	46	5.19E-06	125.41
15–20 m	200	4.27E-06	103.11
20–25 m	666	4.40E-06	106.19
25–30 m	1,579	4.20E-06	101.54
30–35 m	2,561	4.14E-06	99.88
35–40 m	1,687	3.98E-06	96.23
40–45 m	284	4.12E-06	99.53
45–50 m	57	3.16E-06	76.38
50–55 m	4	4.20E-06	101.46
Total	7,103	4.14E-06	100.00

STATE OF ALASKA

Department of Fish and Game

MEMORANDUM

*Division of Commercial Fisheries
Management and Development*

Limnology Section
34828 Kalifornsky Beach Rd.
Soldotna, AK 99669
Phone: 262-9368; Fax: 262-7646

Date: May 25, 1995

To: Ken Tarbox
Area Research Biologist

Dana Schmidt
Principal limnologist

From: Stan Carlson *SLC*
Biometrician

File: SK94AWL.MEM

Subject: Final AWL Estimates for Skilak Lake Sockeye Salmon Fry, fall 1993 to fall 1994.

I would like to describe the statistical estimation methods and provide final AWL estimates for Skilak Lake sockeye fry collected using townets from fall 1993 to fall 1994. You may recall the memo of 4/22/94 (skfry94.mem) in which I briefly described a 3 (depths) \times 3 (areas) stratified sampling design using catch rates (CPUE) to compute stratum weights. The technique was developed based on trials that were conducted in 1993 and was used throughout the 1994 season.

Notation

The notation is split into two groups to help avoid confusion. I did this because fry used for AWL data were often a subsample of the fish caught in each tow; whereas, all captured fish were counted and identified as either sockeye or non-sockeye.

(i) Estimation involving the whole fish population:

C_h = catch rate (CPUE in #/min) of all fish species in stratum h $\subset P \times$

C = total catch rate of fish ($= \sum_h C_h$)

n_h = sample size of fish in stratum h

n_{hs} = number of sockeye salmon sampled in stratum h

h_h = sample proportion of sockeye in stratum h ($= n_{hs}/n_h$)

L = proportion of sockeye in the fish population

(ii) Estimation involving sockeye salmon AWL data:

K_h = catch rate (CPUE in #/min) of sockeye in stratum h

-continued-

K = total catch rate of sockeye ($= \sum_h K_h$)
 a_h = sample size of sockeye in stratum h retained for AWL data
 a_{hj} = number of age- j sockeye sampled in stratum h
 p_{hj} = sample proportion of age- j sockeye in stratum h ($= a_{hj}/a_h$)
 P_j = proportion of the j^{th} age-class in the sockeye population
 L_j = proportion of the j^{th} sockeye age-class in the fish population
 y_{hij} = measurement of y on the i^{th} individual in the j^{th} age-class in stratum h
 y_{hj} = sample total of y for the j^{th} age-class in stratum h ($= \sum_i y_{hij}$)
 \bar{y}_{hj} = sample mean of y for the j^{th} age-class in stratum h ($= y_{hj}/a_{hj}$)
 \bar{Y}_j = population mean of y for the j^{th} age-class

(The variable y represents either fork length or wet weight.)

Assumptions

The following assumptions are necessary for the estimates to be unbiased. In reality, we hope that violations of these assumptions are minimal so that the estimates are approximately unbiased.

1. A random sample of fish is obtained within each stratum.
 2. The target population is representative of the whole fish population.
 3. Catch rates are proportional to fish density.
 4. Measurements (length and weight) and identification (species and age-classes) are made without error.
- s. strata are approximately equal sized*

Estimation Methods

The proportion of sockeye in the lake (L) is estimated by

$$\hat{L} = \frac{1}{C} \sum_h C_h l_h \quad (1)$$

with variance estimate

$$v(\hat{L}) = \frac{1}{C^2} \sum_h C_h^2 \left(\frac{l_h(1-l_h)}{n_h-1} \right). \quad (2)$$

The proportion of sockeye salmon that are age- j (P_j) is estimated by

$$\hat{P}_j = \frac{1}{K} \sum_h K_h p_{hj} \quad (3)$$

with variance estimate

$$v(\hat{P}_j) = \frac{1}{K^2} \sum_h K_h^2 \left(\frac{p_{hj}(1-p_{hj})}{a_h-1} \right). \quad (4)$$

Note that in equations (2) and (4) the finite population correction factor was not included; this is because within-stratum population sizes are unknown and assumed large compared to the sample sizes.

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Length and weight estimates involve domain estimation techniques given, for example, in Cochran (1977). Without going into great detail, the problem essentially involves estimating catch rates (thus stratum weights) for each age-class:

$$\hat{K}_{hj} = K_h(p_{hj})$$

and

$$\hat{K}_j = \sum_h \hat{K}_{hj}.$$

Mean length or mean weight is estimated as

$$\hat{\bar{Y}}_j = \frac{\sum_h \frac{K_h}{a_h} (y_{hj})}{\sum_h K_h \left(\frac{a_{hj}}{a_h} \right)}. \quad (5)$$

The variance estimate is a bit messy because it involves a ratio of two estimates:

$$v(\hat{\bar{Y}}_j) \cong \sum_h \left(\frac{K_h}{\hat{K}_j} \right)^2 \frac{1}{a_h(a_h - 1)} \left[\sum_i (y_{hij} - \bar{y}_{hj})^2 + a_{hj} \left(1 - \frac{n_{hj}}{n_h} \right) (\bar{y}_{hj} - \hat{\bar{Y}}_j)^2 \right]. \quad (6)$$

An estimate of the proportion of age-j sockeye in the whole fish population (L_j) is

$$\hat{L}_j = \hat{L}(\hat{P}_j) \quad (7)$$

with approximate variance

$$v(\hat{L}_j) = \hat{L}^2 v(\hat{P}_j) + \hat{P}_j^2 v(\hat{L}) - v(\hat{L})v(\hat{P}_j), \quad (8)$$

assuming that the proportion of sockeye in the fish population is independent of the age-class composition of sockeye. Results using equations (1), (2), (7), and (8) can be used for hydroacoustic apportionment.

Results

Final estimates using equations (1) to (8), which can be found in Tables 1 to 4, are given for fry collected in September and November 1993 and May to October 1994. In all cases the three areas defined for hydroacoustic enumeration were used in the stratification scheme. September, 1993 samples were divided roughly into surface, 10-15 m, and 20-30 m depth strata. November, 1993 samples were divided roughly into surface and 20-30 m depth strata. In 1994 three depth strata were established and sampled consistently: 0-10 m (surface), 10-30 m, and 30-40 m. Comparability of 1993 and 1994 estimates is therefore somewhat suspect. Separate estimates for each area are also available.

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Table 1. Estimated proportion of sockeye salmon fry in the total fish population of Skilak Lake from fall, 1993 to fall, 1994. Variance estimates, standard errors (SE), and 95% confidence limits (CL) are also given. Stratified random sampling methods were used to compute the estimates.

Date	Proportion	Variance	SE	95% CL	
				Lower	Upper
9/17/93	0.980	7.115E-06	0.0027	0.975	0.985
11/15/93	0.967	9.823E-06	0.0031	0.961	0.973
4/25/94	0.979	8.158E-06	0.0029	0.973	0.984
5/23/94	0.990	1.702E-06	0.0013	0.987	0.993
6/13/94	0.979	6.943E-06	0.0026	0.974	0.985
7/12/94	0.976	2.715E-05	0.0052	0.965	0.986
8/8/94	0.970	3.522E-05	0.0059	0.958	0.981
8/22/94	0.973	1.813E-05	0.0043	0.964	0.981
9/19/94	0.994	2.762E-06	0.0017	0.991	0.997
10/20/94	0.990	1.146E-05	0.0034	0.983	0.997

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Table 2. Estimated proportions of sockeye salmon age classes in the total fish population of Skilak Lake from fall, 1993 to fall, 1994. Approximate variances, standard errors (SE), and simultaneous 95% confidence limits (CL) are given for each sampling period. Stratified random sampling methods were used to compute the estimates.

Date	Age	Proportion	Variance	SE	95% CL	
					Lower	Upper
9/17/93	0	0.929	2.778E-05	0.0053	0.917	0.941
	1	0.051	2.166E-05	0.0047	0.041	0.062
11/15/93	0	0.949	1.722E-05	0.0041	0.940	0.958
	1	0.018	8.374E-06	0.0029	0.012	0.025
4/25/94	0	0.017	2.413E-05	0.0049	0.005	0.029
	1	0.851	2.122E-04	0.0146	0.816	0.886
	2	0.111	1.825E-04	0.0135	0.078	0.143
5/23/94	0	0.181	2.280E-05	0.0048	0.170	0.193
	1	0.770	6.595E-05	0.0081	0.750	0.790
	2	0.039	4.361E-05	0.0066	0.023	0.055
6/13/94	0	0.527	2.124E-05	0.0046	0.516	0.538
	1	0.448	2.428E-05	0.0049	0.436	0.460
	2	0.043	4.642E-06	0.0022	0.038	0.048
7/12/94	0	0.576	3.636E-05	0.0060	0.563	0.590
	1	0.399	3.167E-05	0.0056	0.387	0.412
8/8/94	0	0.733	2.932E-04	0.0171	0.695	0.772
	1	0.236	2.762E-04	0.0166	0.199	0.274
8/22/94	0	0.849	1.303E-04	0.0114	0.824	0.875
	1	0.123	1.175E-04	0.0108	0.099	0.148
9/19/94	0	0.873	1.691E-04	0.0130	0.844	0.902
	1	0.121	1.670E-04	0.0129	0.092	0.150
10/20/94	0	0.786	2.208E-04	0.0149	0.752	0.819
	1	0.204	2.142E-04	0.0146	0.171	0.237

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Table 3. Estimated age-class proportions (composition) of sockeye salmon in Skilak Lake from fall, 1993 to fall, 1994. Variance estimates, standard errors (SE), and simultaneous 95% confidence limits (CL) are given for each sampling period. Stratified random sampling methods were used to compute the estimates.

Date	Age	Proportion	Variance	SE	95% Confidence Limits	
					Lower	Upper
9/17/93	0	0.948	2.254E-05	0.0047	0.937	0.958
	1	0.052	2.254E-05	0.0047	0.042	0.063
11/15/93	0	0.981	8.950E-06	0.0030	0.975	0.988
	1	0.019	8.950E-06	0.0030	0.012	0.025
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4/25/94	0	0.018	2.519E-05	0.0050	0.006	0.030
	1	0.869	2.154E-04	0.0147	0.834	0.905
	2	0.113	1.904E-04	0.0138	0.080	0.146
5/23/94	0	0.183	2.321E-05	0.0048	0.171	0.195
	1	0.778	6.625E-05	0.0081	0.758	0.797
	2	0.039	4.449E-05	0.0067	0.023	0.055
6/13/94	0	0.538	2.014E-05	0.0045	0.527	0.549
	1	0.458	2.388E-05	0.0049	0.446	0.470
	2	0.004	4.840E-05	0.0070	-0.012	0.021
7/12/94	0	0.591	2.873E-05	0.0054	0.579	0.603
	1	0.409	2.873E-05	0.0054	0.397	0.421
8/8/94	0	0.756	2.918E-04	0.0171	0.718	0.795
	1	0.244	2.918E-04	0.0171	0.205	0.282
8/22/94	0	0.873	1.239E-04	0.0111	0.848	0.898
	1	0.127	1.239E-04	0.0111	0.102	0.152
9/19/94	0	0.878	1.690E-04	0.0130	0.849	0.908
	1	0.122	1.690E-04	0.0130	0.092	0.151
10/20/94	0	0.794	2.181E-04	0.0148	0.760	0.827
	1	0.206	2.181E-04	0.0148	0.173	0.240

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Table 4. Mean fork length (mm) and wet weight (g) of sockeye fry age-class cohorts in Skilak Lake from fall, 1993 to fall, 1994. Standard Error estimates (SE) and 95% confidence limits (CL) are given for each age-class and sampling period. Stratified random sampling methods were used to compute the estimates.

Date	Age Class	n	Length (mm)				Weight (g)			
			mean	SE	95% CL		mean	SE	95% CL	
					lower	upper			lower	upper
9/17/93	0	2755	47.5	0.11	47.2	47.7	1.15	0.009	1.13	1.17
	1	124	75.5	0.42	74.7	76.3	4.50	0.072	4.36	4.65
11/15/93	0	1766	47.9	0.11	47.7	48.1	1.03	0.008	1.01	1.05
	1	42	75.0	0.68	73.7	76.4	4.20	0.127	3.95	4.46
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4/25/94	0	10	28.7	0.31	28.0	29.3	0.22	0.011	0.19	0.24
	1	574	53.3	0.24	52.8	53.8	1.67	0.022	1.63	1.72
	2	65	76.9	0.57	75.8	78.0	4.45	0.087	4.28	4.63
5/23/94	0	186	29.6	0.07	29.5	29.8	0.24	0.004	0.23	0.25
	1	684	54.0	0.19	53.7	54.4	1.82	0.020	1.78	1.86
	2	34	82.0	2.02	78.0	86.0	5.75	0.444	4.86	6.64
6/13/94	0	502	30.6	0.09	30.4	30.8	0.27	0.005	0.26	0.28
	1	388	57.4	0.24	56.9	57.9	2.23	0.026	2.18	2.28
	2	34	107.7	9.52	88.6	126.7	15.36	2.911	9.54	21.19
7/12/94	0	483	35.3	0.13	35.0	35.6	0.48	0.007	0.46	0.49
	1	251	63.7	0.28	63.1	64.2	3.03	0.042	2.94	3.11
8/8/94	0	434	42.5	0.19	42.2	42.9	0.92	0.013	0.90	0.95
	1	140	67.2	0.31	66.6	67.8	3.58	0.046	3.48	3.67
8/22/94	0	788	44.9	0.16	44.6	45.3	1.09	0.012	1.07	1.11
	1	108	68.1	0.35	67.5	68.8	3.66	0.056	3.55	3.78
9/19/94	0	687	50.1	0.15	49.8	50.4	1.42	0.013	1.39	1.45
	1	110	68.1	0.35	67.4	68.8	3.56	0.053	3.46	3.67
10/20/94	0	597	54.5	0.16	54.1	54.8	1.51	0.014	1.48	1.54
	1	157	72.8	0.28	72.2	73.4	3.72	0.045	3.63	3.81